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AUTHOR(S):

Kikuta, Jun; Ito, Tatsuhide; Tomiyama, Izuru;
Yamamoto, Shu; Yamada, Tadashi

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New subway-integrated city logistics system

Jun Kikuta^{a*}, Tatsuhide Ito^a, Izuru Tomiyama^b, Shu Yamamoto^c, Tadashi Yamada^d^a*Docon, Atsubetsu-ku, Sapporo, 004-8585, Japan*^b*Yamato Transport Co. Ltd, Japan*^c*Mayor's Policy Planning Office, City of Sapporo, Cyuou-ku, Sapporo, 060-8611 Japan*^d*Department of Urban Management, Kyoto University, Nishikyo-ku, Kyoto, 615-8540, Japan*

Abstract

In this paper, we propose a new city logistics system by integrating public subway service with conventional freight vehicle operation to transport goods effectively from the suburbs to the city center. This system mitigates urban transport problems, such as traffic congestion, environmental impact, and delivery delay, particularly during winter when heavy snowfall impairs traffic operation. To verify the effectiveness of this system, we conducted a pilot project. From our pilot project, we found that this system can be expected to enhance the smooth flow of goods, reduce the number of on-street unloading vehicles, and protect the environment. We also confirmed that the public positively accepted this project.

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Keywords: Railway; underground; urban freight transport

1. Introduction

Most cities are interested in the smooth movement of freight in their spatially limited urban centres where people and goods concentrate. There is, therefore, a need to implement the new systems, which facilitate the efficient transport of goods within urban areas, including railway freight transport systems (e.g., Robinson and Mortimer (2004) [1]; Arvidsson (2010) [2]) and underground ones (e.g., Ooishi and Taniguchi (1999) [3]; Wiegmans et al. (2010) [4]). In particular, the city of Sapporo (a population of 1.9

* Corresponding author. Tel.: +8-11-8011590; fax: +81-11-8011591.
E-mail address: [jk1181@docon.jp](mailto:j1181@docon.jp)

million) in northern Japan suffers serious winter logistics problems as snow-confined road spaces drastically decrease transport efficiency. To address these problems, we examine the possibility of integrating the Sapporo city subway system with conventional truck transportation service to distribute goods more smoothly between the suburbs and the city centre. On the basis of the results of further experiments, we will propose effective measures for urban transport problems.

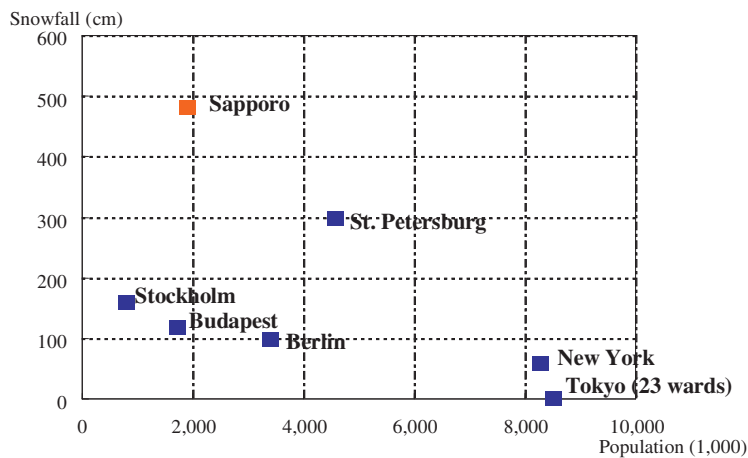


Fig. 1. Population and snowfall in the World's major cities (Sources: Population: 2005 National Census from Statistics Bureau, Ministry of Internal Affairs and Communications, Snowfall in Tokyo and Sapporo Climate Statistics for Nov. 2009-Mar. 2010 from Japan Meteorological Agency, Snowfall in other cities from Snow & Ice Data Book 2002, 2006 (PIARC), Winter Cities Now Sapporo)

2. Urban transport problems in Sapporo

Sapporo is a large populous city where snow falls heavily during the winter. Cumulative snowfall from November to March averages to nearly 500 cm and snow depth at the end of February is approximately 80 cm.



Fig. 2. On-street unloading vehicle during winter

Congestion caused by snowfall and constriction of road width due to roadside snow pile particularly impairs winter traffic efficiency in the city center. City logistics problems also include blockage by on-street unloading vehicles, environmental impact, snow-induced traffic congestion, and delivery delays because of icy road surfaces. Thus, some measures need to be taken to address these problems.

On-street unloading vehicles particularly aggravate the traffic problem. Nearly 63% of truck drivers responding to a 2006 logistics survey expressed that they loaded and unloaded on the street in the center of Sapporo.

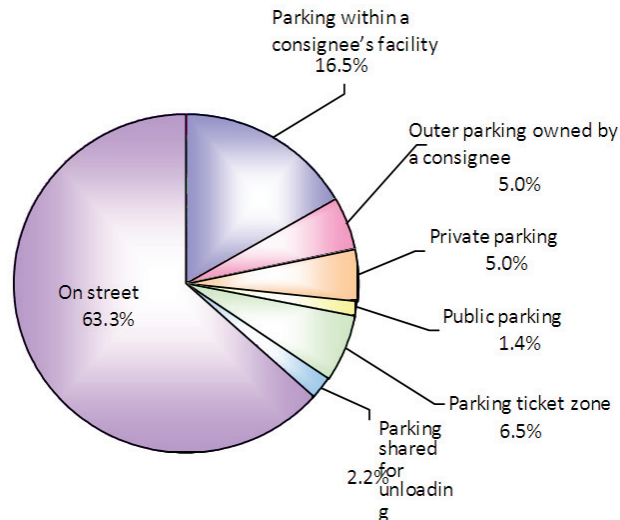


Fig. 3. Unloading sites in Sapporo city center (Source: Questionnaire survey on the logistics by Hokkaido Regional Development Bureau, 2006)

The parking duration of freight vehicles tends to be longer in the city center, whereas it is shorter in the Hiragishi district, which is at a distance of 10 to 15 min from the center by car. Because commercial facilities and business offices are densely accumulated in the city center, freight vehicles remain parked for an extended period to complete deliveries to several destinations while other vehicles await available space. In contrast, parking places are available close to delivery destinations most of the time in the Hiragishi district.

During winter, fewer passenger cars and taxis generally commute and seek parking. However the number of freight vehicles is unchanged between summer and winter on the whole.

For citizens, deliverers, and consignees, traffic conditions in the Sapporo city center create the following problems:

1. For citizens:
 - On-Street unloading vehicles obstruct pedestrian passages.
 - Passengers are obstructed from getting on and off public transport.
 - Environment suffers from noise and emissions of freight vehicles parking for extended periods.
2. For freight carriers:
 - Delivery efficiency decreases because of traffic congestion in the city center.
 - Delivery efficiency decreases because of restricted space for driving and parking during winter.

3. For consignees:

- Sales opportunities are decreased because of delayed delivery when traffic is congested.
- Goods may be damaged while unloading hastily within short parking duration.
- Although underground shops with minimal storage space require smaller and more frequent deliveries, the current truck delivery service cannot meet their needs.

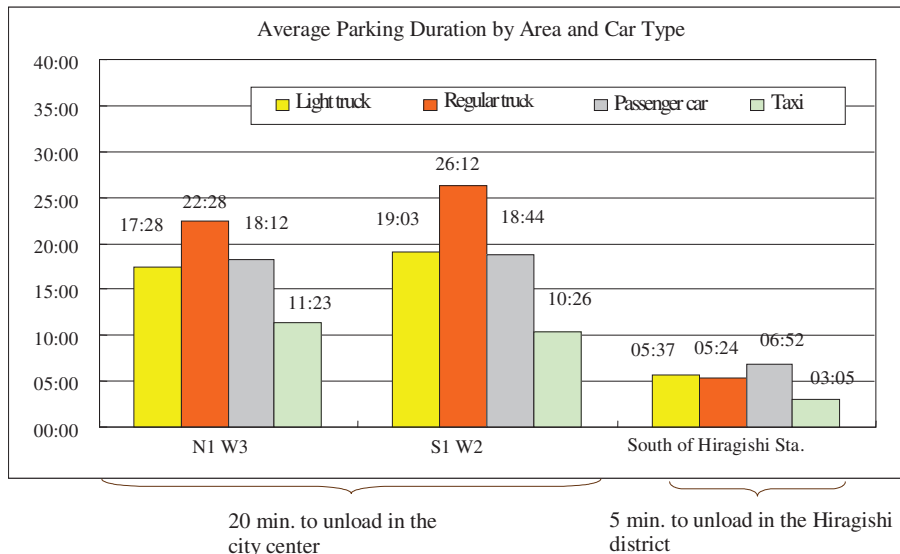


Fig. 4. Parking duration (Source: Questionnaire survey on the logistics (Hokkaido Regional Development Bureau, 2006))

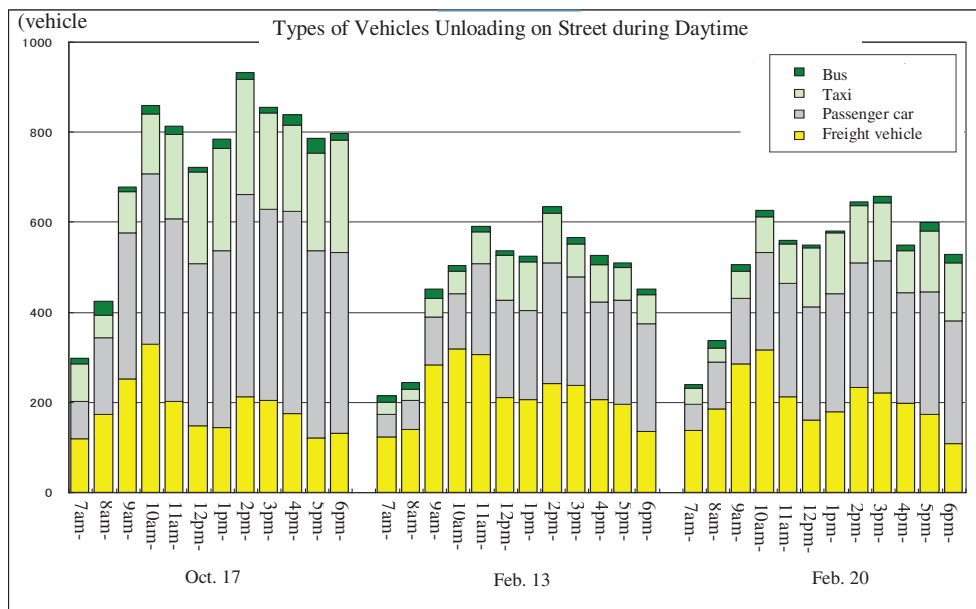


Fig. 5. Number of on-street unloading vehicles

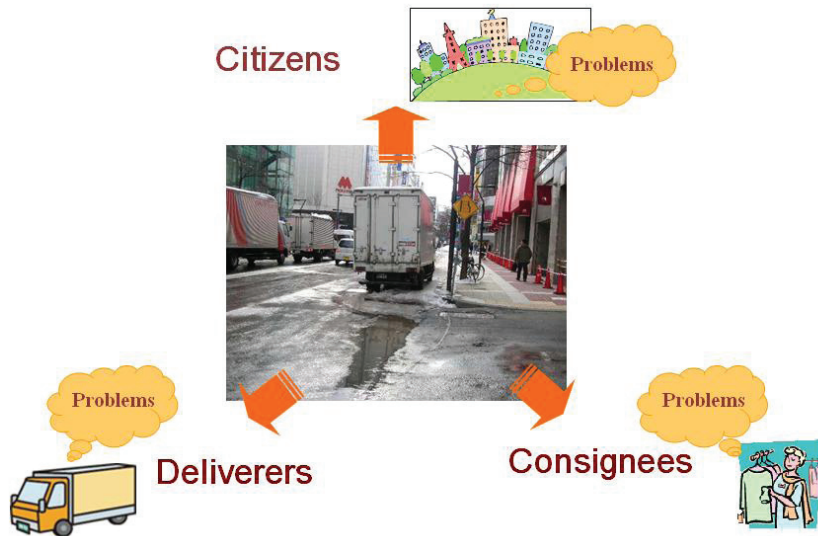


Fig. 6. Logistics problems in the city center

The current freight system is limited in its ability to resolve the aforementioned problems. Thus, drastic measures need to be taken.

3. Solutions offered by the subway-integrated city logistics system

Traffic congestion due to heavy snowfall is a challenge to Sapporo. However, we propose a workable approach that can provide a radical solution to intramural transport problems for business centers of many cities. We have designed a new delivery system by integrating Sapporo's existing city subway system with the current truck delivery service that operates exclusively between Sapporo's suburbs and its city center.

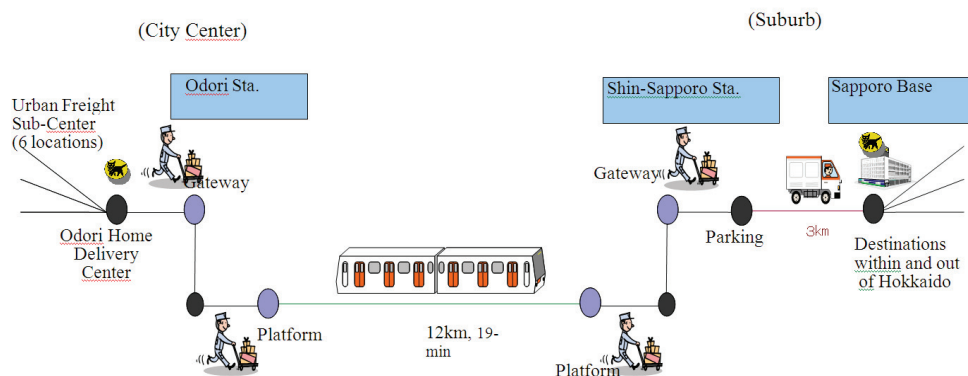


Fig. 7. Conceptual image of the new subway-integrated logistics system

3.1. Proposal for the new subway-integrated city logistics system

We designed a new city logistics system that uses the subway, then analyzed its feasibility. Our new city logistics system has the following merits: (a) deliverers can escape traffic congestion and reduce delays by changing their means of transport from truck to subway; (b) traffic congestion is mitigated and urban environment is improved with lower CO₂ emissions as the number of operating freight vehicles and on-street unloading vehicles reduces; (c) merchants in the central underground shopping complex can overcome shortages of goods through quick and frequent deliveries; and (d) public transportation bureau can increase its revenue by providing freight service during off-peak hours.

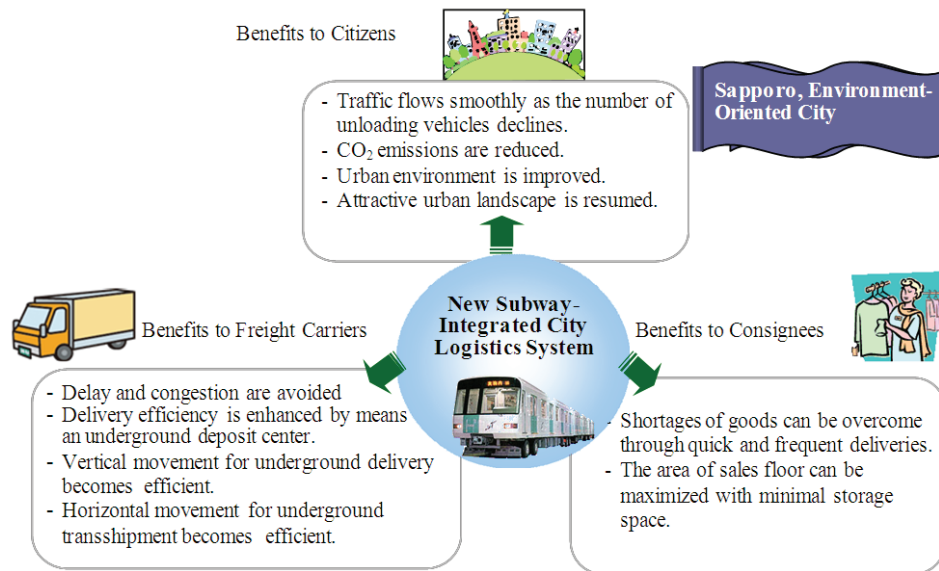


Fig. 8. Benefits of the new city logistics system

3.2. Outline of the new city logistics system pilot project

To determine whether the new subway-integrated city logistics system is plausible as a new transport strategy, we tested its effectiveness and feasibility by an experiment outlined below.

- Period: September 2–15, 2010 (two weeks)
- Route and hour: the procedure was conducted three times during off-peak hours from 10:30 to 14:00 between the Yamato Transport Sapporo Base (suburb) and the Odori Home Delivery Center (city center) for a distance of approximately 10 km, which includes the Sapporo Subway Tozai Line between Shin-Sapporo Station and Odori Station.
- Method: a hand cart (w = 500 mm, h = 900 mm, d = 700 mm, gross weight = 60 kg) loaded aboard an ordinary passenger subway car (on a wheelchair floor).
- Course: the cart was taken from the home delivery center to the subway ticket gate in an elevator. Passing through the ticket gate, the cart was lifted down to the subway platform and loaded on a subway car. On reaching the destination station, the cart was lifted from the platform to the ticket gate. After exiting the ticket gate, the cart was taken above ground.

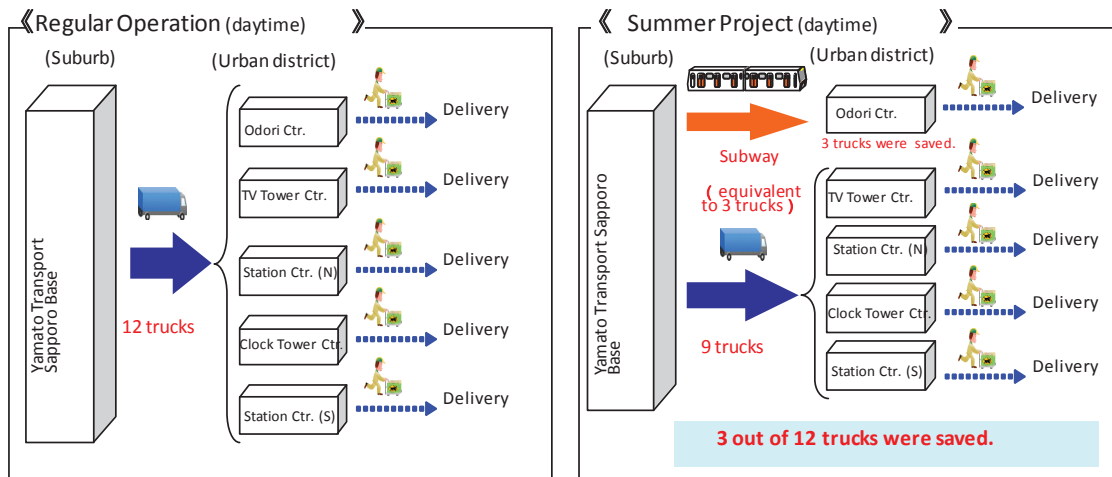


Fig. 9. Outline of the subway-integrated city logistics project



Fig. 10. Poster announcing the pilot project

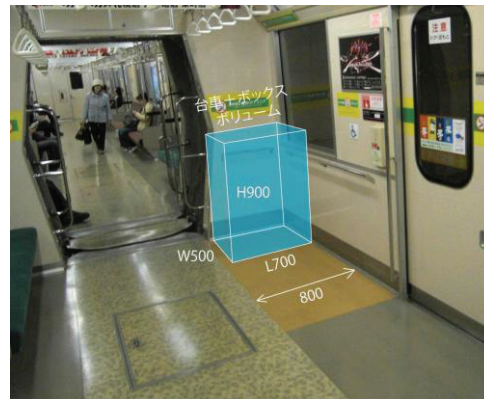


Fig. 11. Wheelchair space used for delivery cart



Fig. 12. Delivery cart used in the project

4. Public evaluation of the pilot project

This pilot project involved the city subway system used daily by numerous Sapporo citizens. In addition, if the project is to be developed for future implementation, it is necessary to understand the opinions of Sapporo taxpayers. Therefore, we conducted a questionnaire survey and an on-board monitoring survey.

4.1. Objective and method

The objective and the method of each survey were as follows:

- Public questionnaire
 - Objective: to research people's interests in environmental measures and their evaluations and opinions of the significance of the project.
 - Subject: men and women age 20 and older living in Sapporo.
 - Method: via the Internet.
 - Sample size: 200 participants evenly distributed across all gender and age categories.

Implementation Guidelines

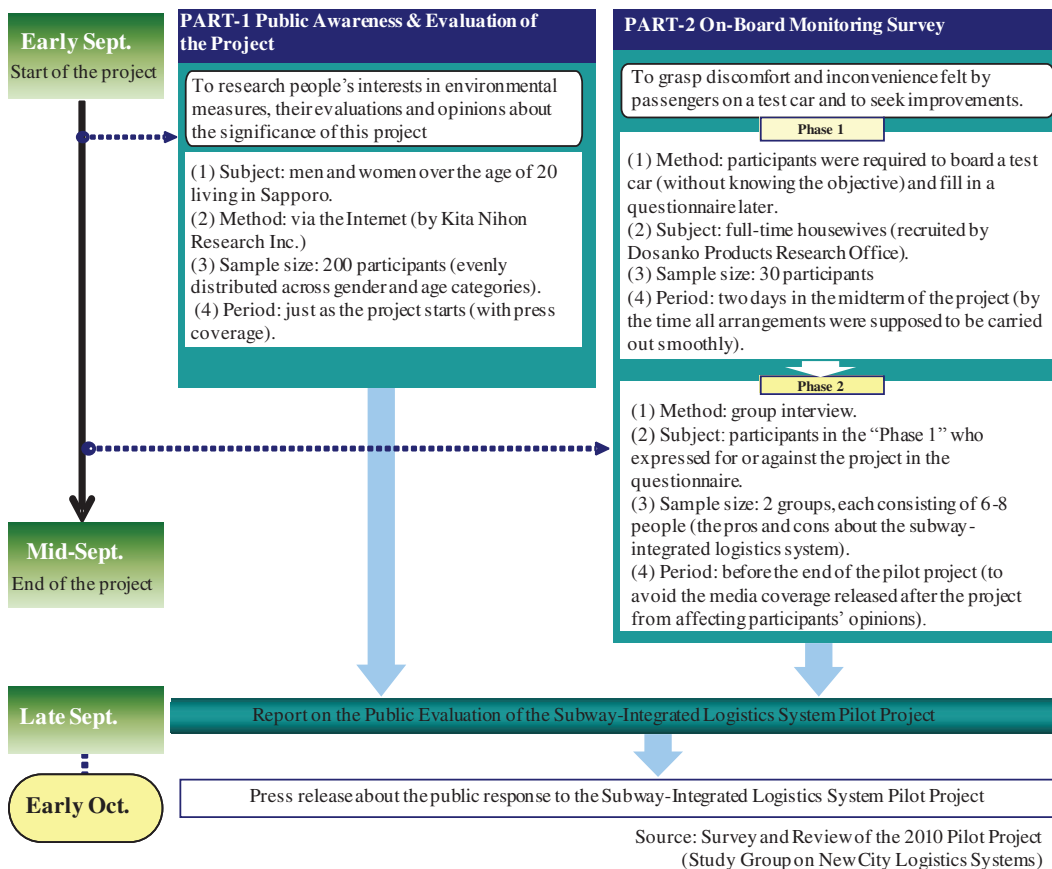


Fig. 13. Public evaluation of the pilot project

- On-board monitoring survey-1
 - Objective: to assess passengers' discomfort and inconvenience on a test car and to seek improvements.
 - Method: participants were required to board a test car (without knowing the test objective) and answer a questionnaire later.
 - Subject: full-time housewives, because the test was conducted during daytime.
 - Sample size: 30 participants.
 - Period: two days in the midterm of the project (by the time all arrangements were supposed to be carried out smoothly).
- On-board monitoring survey-2
 - Method: group interview.
 - Subject: participants in on-board monitoring survey-1, who expressed for or against the project in the questionnaire.
 - Sample size: two groups, each consisting of six people (having either positive or negative opinions about the subway-integrated logistics system).
 - Period: before the end of the pilot project (because test results might have been publicized by the media after the project, thereby affecting participants' opinions).

4.2. Evaluation results of the pilot project

4.2.1. Results of the public questionnaire survey

Nearly 90% of respondents supported the subway-integrated logistics project with positive opinions on the effective use of the Sapporo subway system as a city asset.

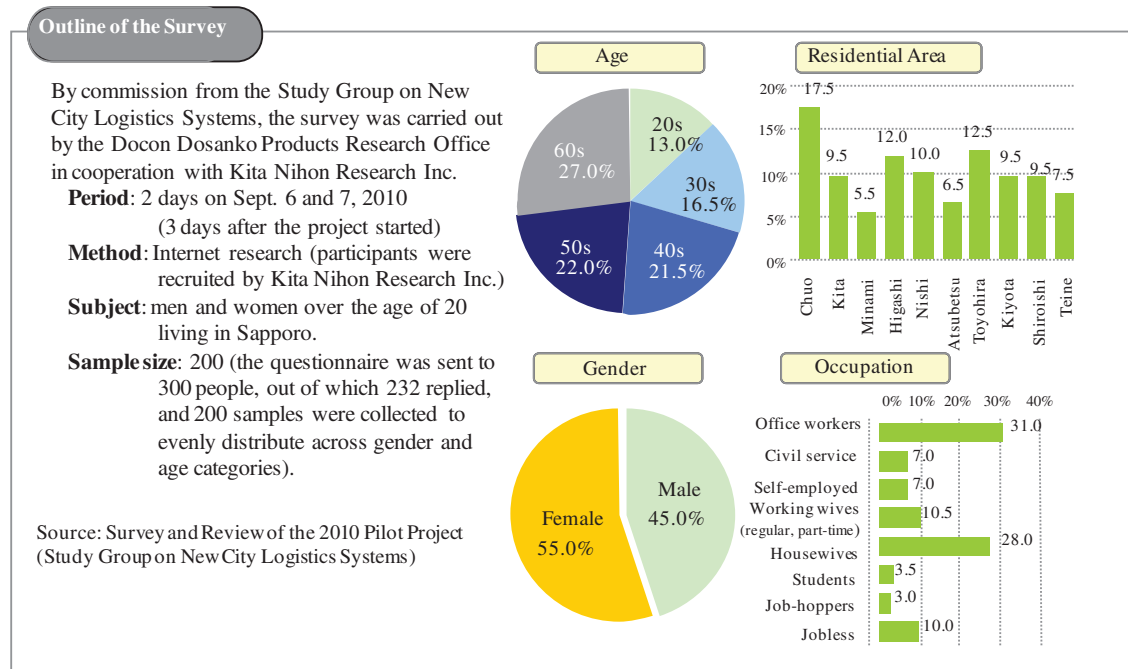


Fig. 14. Outline of the public questionnaire survey

They also supported the system for the mitigation of traffic noise and congestion, the improvement of the urban environment by reducing CO₂ emissions, and the prevention of global warming. Some respondents expressed concerns about congestion and safety management at a subway station owing to mixed loading of passengers and carts, while others questioned the profitability of the project.

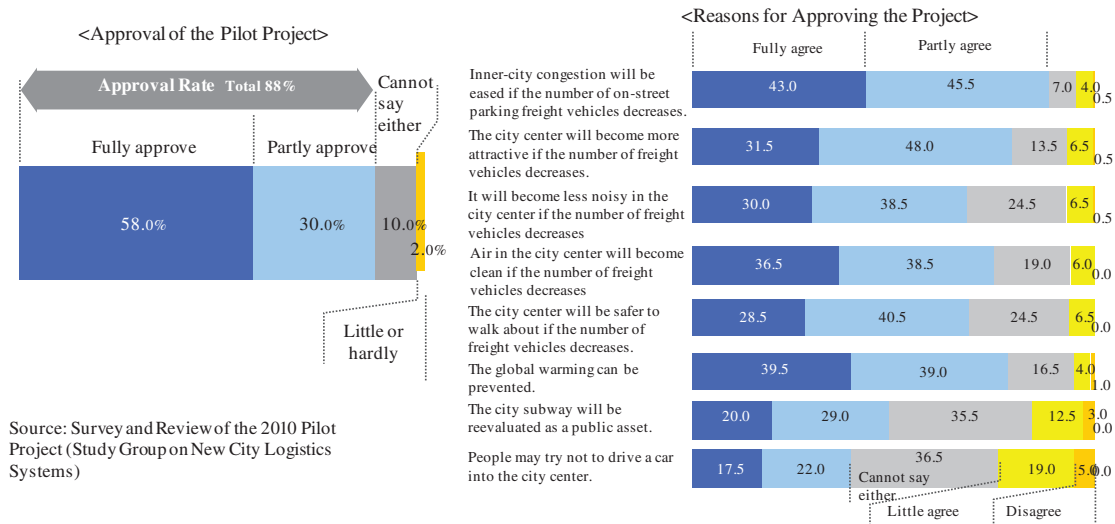


Fig. 15. Results of public questionnaire survey-1

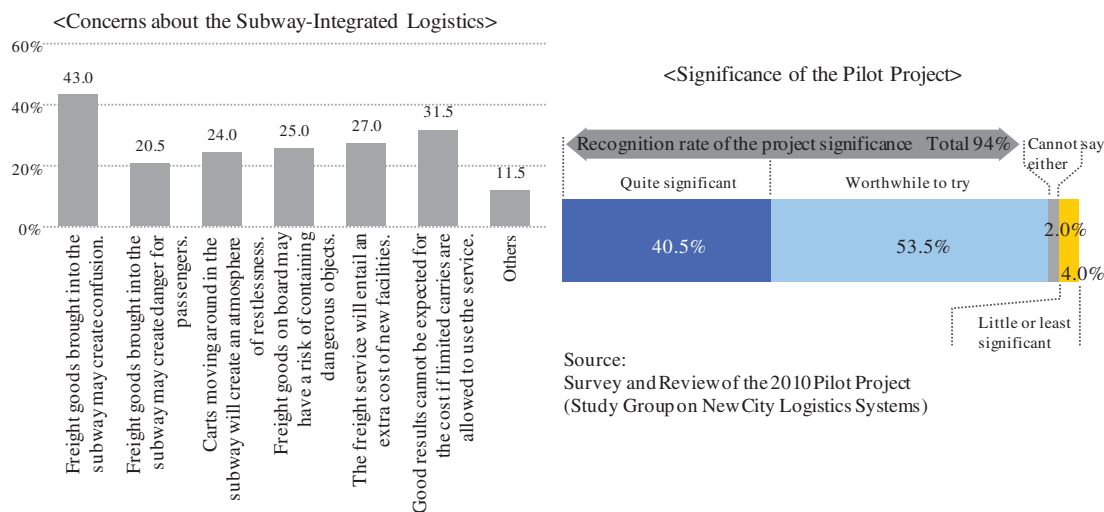


Fig. 16. Results of public questionnaire survey-2

4.2.2. Results of the on-board monitoring survey

In the on-board monitoring survey, nearly 80% of participants did not feel annoyed or uncomfortable while boarding the subway alongside delivered goods. Most supported the idea of separating goods and passengers by using one car exclusively for freight.

Outline of the Survey

By commission from the Study Group on New City Logistics Systems, the survey was carried out by the Docon Dosanko Products Research Office in cooperation with Kita Nihon Research Inc.

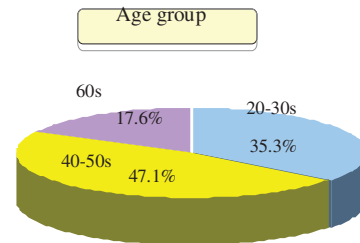
Period: 2 days on Sept. 9 and 10, 2010

(almost a week after the project started)

Method: participants were required to board a test car (without knowing the test objective) and fill in a questionnaire later.

Subject: full-time housewives between ages of 20s and 60s living in Sapporo (recruited by Kita Nihon Research Inc).

Sample size: 30 (4 additional monitors on board in reserve.)



Source:
Survey and Review of the 2010 Pilot Project
(Study Group on New City Logistics Systems)

Subway Schedule for Monitors

		Scenario A (Down train)	Scenario C (Down train)	Scenario B (Up train)
		4 participants	4 participants	7 participants
Sept. 9		Odori → Shin-Sapporo 10:33 10:53	Odori → Shin-Sapporo 13:14 13:34	Shin-Sapporo → Odori 13:33 13:53
	Alteration(1)	10:40 11:00	13:21 13:41	13:40 14:00
	Alteration(2)	10:47 11:07	13:28 13:48	13:47 14:07
Sept. 10		4 participants	3 participants	8 participants
		Odori → Shin-Sapporo 10:33 10:53	Odori → Shin-Sapporo 13:14 13:34	Shin-Sapporo → Odori 13:33 13:53
	Alteration(1)	10:40 11:00	13:21 13:41	13:40 14:00
	Alteration(2)	10:47 11:07	13:28 13:48	13:47 14:07
Total		8 participants	7 participants	15 participants

Fig. 17. Outline of the on-board monitoring survey

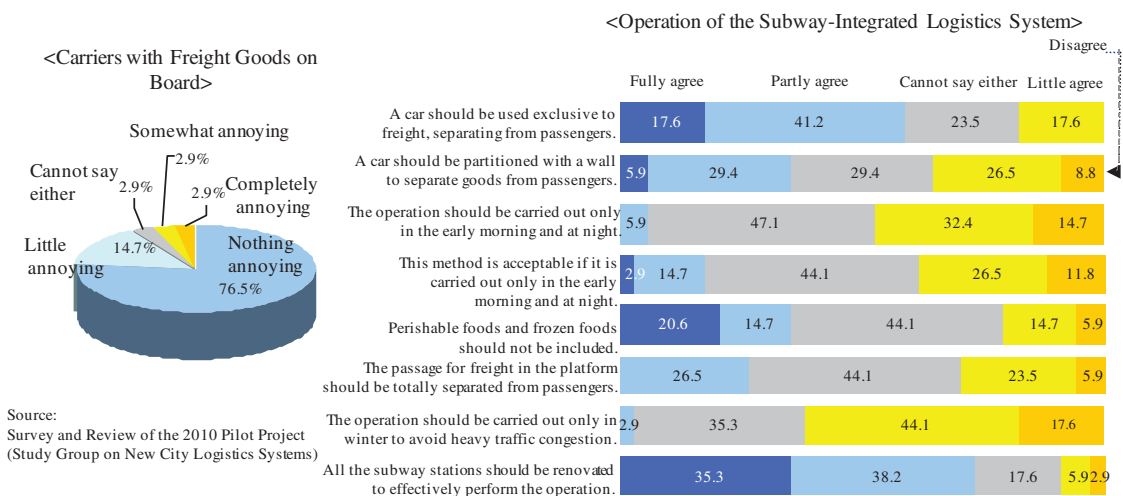


Fig. 18. Results of the on-board monitoring survey

4.2.3. Opinions from the group interview

In the group interview, most respondents expressed that ‘mitigation of traffic congestion’ would be a more convincing reason for the public to become aware of the effectiveness of the project than ‘CO₂ reduction,’ and some wanted to know the expected economic effects.

As for the future subway-integrated logistic system, participants with skeptical opinions requested that more tests should be continuously performed. This suggests that the subway-integrated logistics system is expected to gain a better understanding from the public through a series of experiments. The importance of realistic winter tests to identify reliable effects was also pointed out.

Outline of the Survey

By commission from the Study Group on New City Logistics Systems, the survey was carried out by the Docon Dosanko Products Research Office in cooperation with Kita Nihon Research Inc.

Method: selected participants who got in a test car (without knowing the test objective) were required to discuss in a group interview.

Subject: those participants were organized into the following two groups according to their questionnaire answers.

Group 1 in favor of the project –

The number of participants by age

20s: 1, 30s: 1, 40s: 1, 50s: 2 and 60s: 1

Group 2 skeptical of the project–

The number of participants by age

30s: 2 and 40s: 3

Sample size: a total of 11 participants (6 in Group 1 and 5 in Group 2)

Period: Saturday, Oct. 16, 2010, 2 hours for each group

(1) 10:30-12:30 (2) 14:30-16:30

Source:

Survey and Review of the 2010 Pilot Project
(Study Group on New City Logistics Systems)



(1) Group in favor of the project



(2) Group skeptical of the project

Fig. 19. Outline of the group interview

5. Prospects for future experiments and analyses

To obtain basic information on the project’s potential safety, environmental efficiency, and business feasibility, we tested the subway by transporting delivery goods in an experiment. The results showed that delivering goods by subway can effectively serve as a substitute for conventional truck transport.

We must continuously perform trial-and-error experiments and solve problems to achieve the goals of environmental protection and business efficiency. For that, we will suggest to have delivery goods currently transported by truck partially board on the subway to lay the foundations of the future subway-integrated logistics system. We also plan to build an underground deposit center to examine the efficient handling of subway-loaded goods. Moreover, to establish an underground logistics system for underground shopping complexes and surrounding buildings in the future, we will conduct further studies.

Specifically, an examination of the “transshipment” smoothness at a deposit center is one of our important tasks. In this scheme, freight goods brought into the Yamato Home Delivery Center will be transported by means of subway instead of truck for both morning delivery and afternoon delivery. In

other words, the transshipment efficiency at the deposit center will be reviewed for both morning and afternoon deliveries to reduce environmental load of carrying small quantities of goods in a 4t truck during daytime. We will also consider the feasibility of hauling goods from more than one freight carrier to enhance the prospect for future development.

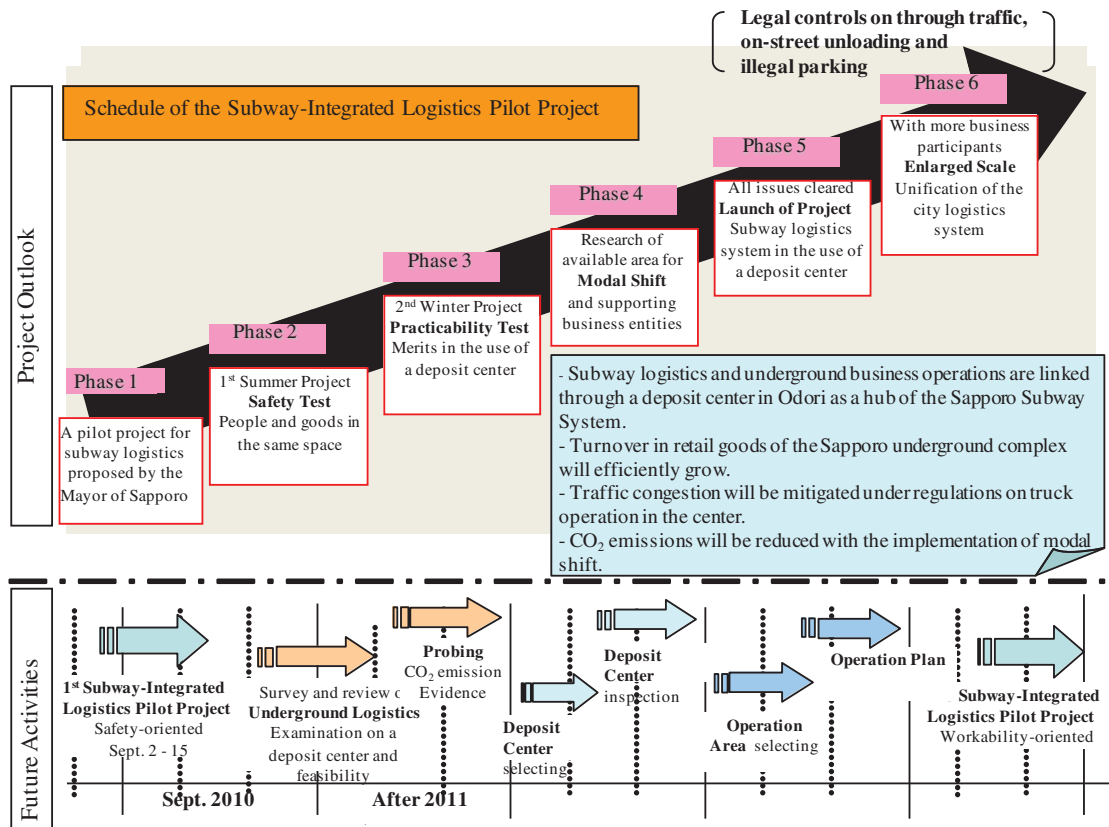


Fig. 20. Prospects of the subway-integrated logistics pilot project

As a result, if transport efficiency of subway and deposit centers is verified in our study, the superiority of an underground logistics system may have its appeal for underground shop owners and office building managers. Thus, the system development will proceed on the commercial base.

We will also examine transport methods (e.g., exclusive use of subway car space), expansion of service area coverage (e.g., entire subway network and an effective distribution system through the relocation of cooperative depots), and formulation of guidelines for the entry of new carriers (e.g., safety standards and freight charges). Simultaneously, simulations of congestion and environmental problems will be performed to identify their effects on the intramural transport system.

6. Conclusion

From an experiment based on the subway system in Sapporo, we have discovered a new potential solution to urban traffic and environmental problems. We will pursue this project and assess its economic feasibility for future practical use, on the basis of which effective measures will be proposed to policymakers.

In particular, we will approach the concerned authorities about deregulating the permission for goods to be transported by subway, which only serves passengers today. Simultaneously, we will propose to restrict on-street unloading of vehicles in order to expect numerous social and economic benefits.

Social significance: (a) restrict on-street unloading of vehicles by offering alternative transport; (b) mitigate environmental problems; (c) utilize existing infrastructure more effectively (e.g., subway and underground shopping complex).

Economic significance: (a) increase revenues of the public transportation bureau; (b) provide new commercial services in the urban center (quick and frequent delivery of goods and increasing use of the public transport); and (c) enhance attractiveness by expanding the sales floor area of underground shops.

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